

## **Sylvicultural procedures in catchment areas of the mountain streams as exemplified by the Skrzyczne massif in Poland**

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### **ABSTRACT**

Extensive disintegration of spruce forests in the Beskidy Mts. in South Poland generates a need to regenerate sizeable areas as well as to rebuild forest stands which have defended themselves against breakdown. In practice, the magnitude of relevant management tasks does not allow for keeping up with the progressive destruction of forest, especially at higher altitudes, where natural regeneration does not occur as much as necessary. In addition, the species composition is limited to spruce, sometimes accompanied by beech and fir, whereas other species have a negligible share. What may be helpful in solving this problem is the method of regeneration of such areas and of establishment of under-canopy cultures, consisting of patchwork, multi-stage regeneration task performance, starting from the areas with the best chance of reforestation success and using the existing self-sown trees. Such areas undoubtedly include habitats with better water balance, i.e. humid habitats (in the case of larger areas, distinguished in the forest management plan as humid forest site types). The aim of the present study was to propose management of watercourses and headwater areas in the region of the Skrzyczne massif where the selected catchments are situated on the southern (the Malinowski Stream) and the northern (the Roztoka Czysta stream) slopes of this massif. The research was carried out in August 2012 and included juxtaposition of available hydrological maps with actual field conditions along with identification of springs and streams and the course of their beds in order to update the existing data. The updating of the forest numerical maps in the existing databases of the State Forests IT System (SILP) included verification of the course of streams and determination of their nature (permanent or periodic) with a division into the existing ones and the added ones. The data was recorded against the background of the division of the forest surface, contour lines, major roads, climate and plant floors and forest habitat types. The total length of streams was ascertained. The catchment areas and areas along their beds were determined by adopting variable distances from the beds, depending on climate and plant zones and the slope gradient. The adopted distances were: 5 m in the upper forest zone, 10 m in the middle forest zone, 20 m in the lower forest zone on both sides of the bed and in the headwater area within the radius of 10 m from a source. Specific sylvicultural procedures in headwater areas and in the neighbourhood of watercourses were described in each climatic and vegetation zones.

### **KEY WORDS**

headwater, watercourses, climatic and vegetation zones, Beskidy Mts., Poland

## INTRODUCTION

Extensive disintegration of spruce forests in the Beskidy Mts. creates considerable areas for regeneration and rebuilding of the stands which still resist this phenomenon (Małek et al. 2012). In practice, the magnitude of relevant tasks does not allow for keeping up with the progressive destruction of the forest in this regard, especially in higher altitudes, where there is not enough natural regeneration. In addition, the species composition is limited to spruce, sometimes accompanied by beech and fir, whereas other species have a negligible share (Barszcz and Małek 2003).

What may be helpful in solving this problem is the method of regeneration of such areas and of establishment of under-canopy cultures, consisting of patchwork, multi-stage task performance, starting from areas with the best chance of reforestation success and using the existing self-sown trees (Małek et al. 2012a, b; 2010a, b).

Such areas undoubtedly include habitats with better water balance, i.e. humid habitats (in the case of larger areas, distinguished in the forest management plan as humid forest site types). Forest humid habitats were pointed out in the studies by Krause (2010) and Hrkal (2004) from the Czech Republic as well as Rothe and Mellert (2004) from Germany. In Poland, special attention to such habitats was drawn in the case of the Sudety Mts. (Sienkiewicz et al. 1995; Kucharska et al. 1995; Pierzgalski et al. 2009). The surface and percentage shares of two groups of areas along with their structure in relation to forest zones (altitude) were described in that study for the first time. The study also described the significance of the area of the latter group, i.e. around headwaters and a stream, which in the five examined forest districts of the Beskid Śląski and Żywiecki Mts. in the Regional Directorate of the State Forests in Katowice is comparable to the area of humid forest site types.

The aim of the present study was to propose management of watercourses and headwater areas in the region of the Skrzyczne massif.

### The study area

The Beskidy Mts. are a group of mountain ranges of the Outer Carpathians. In their western part, the largest ranges are the Beskid Śląski and Beskid Żywiecki. Even though the ranges are located within a short distance,

they notably differ in terms of the geological structure. The Beskidy Mts. are one of the youngest mountains as they were uplifted during the Alpine folding and in the late Tertiary. The folding followed from the south so the layout of mountain ranges generally tags along latitude parallels, i.e. their northern slopes are characteristic of much larger declines than the southern slopes. The present relief of the Beskid Śląski is mainly due to erosion caused by flowing waters. Strong declines cause vigorous erosion which widens valleys, and the valleys are flattened at creek mouths. Slope and valley landslides caused by water erosion (undercutting the slopes) or sandstone sliding down on wet shale play an important role in relief modelling ([www.wsa.bielsko.pl](http://www.wsa.bielsko.pl), Małek and Gawęda 2004 after BULiGL 1998). Skrzyczne (1257 m a.s.l.) is the highest mountain in the Beskid Śląski and belongs to the Barania Góra range.

### Geology

The basal complex of the Beskidy Mts. is formed by alternately layered sedimentary rocks: sandstones and shales, and less frequently by conglomerates, marls and limestones, shaping the so-called Carpathian flysch. Its thickness reaches 6 km. There are no major fossils there but it is believed that the deposits developed in the deep sea. Later on, tectonic movements caused the folding and shifting of flysch layers one onto another as large caps or nappes, separated from the older bedrock. Three wide-ranging nappes are distinct in the Beskidy Mts.: the Silesian, Skole and Magura ones. The study area lies within the Silesian Nappe, which extends continuously along the Carpathian arc and, apart from the Beskid Śląski, also forms the Little Beskid and the foothills. There are several layers in it, including the Godula layers, that form the Skrzyczne massif reaching the thickness of nearly 2000 m. The sandstones of these layers are characteristic of an admixture of calcium carbonate and binder that is usually siliceous, and less often clayey or carbonate. The sandstones weather less easily than the adjacent Istebna sandstones. The Godula layers are divided into three levels: the lower, middle and upper ones, which are visible to varied degrees owing to folds. In the research area, consecutive levels are represented by: glauconitic flinty thin-bedded sandstones and green shales, glauconitic thick-bedded sandstones and green shales as well as thin-bedded flinty sandstones with green and dark slate and – around the Ma-

linowska Rock – polygenic conglomerates. The tertiary rock-waste clays, gravels, sands and river clays lie on these deposits. Due to the diagonal arrangement of rock layers which form the ridges, the northern mountain slopes in the Silesian Beskid are steep or even rugged and undergo erosion and weathering easily, whereas the southern slopes are gentle. The gradient of the southern slopes is consistent with the direction and angle of the dip of the layers forming the southern slopes ([www.wsa.bielsko.pl](http://www.wsa.bielsko.pl)). Soils formed on the geological formations described above are mainly podzolic but also brown and rankers. Soils in the Czyrna catchment are characteristic of a finer grain size than soils in the Malinowski Stream catchment, which can confirm the hypothesis of easier weathering of rocks on the northern slopes. The process of soil podzolisation was probably, as in other parts of the Beskid, enhanced by inappropriate management measures undertaken, but above all this is due to the so-called “spruce-mania” (Małek 2010).

### Hydrogeological conditions

The Western Beskidy Mts., being a mountain range located as the first one on the path of humid oceanic air masses, are characterized by a relatively large amount of rainfall. Its annual amount usually does not fall below 1,200 mm, however, some precipitation posts have recorded the annual rainfall of up to 2,000 mm. In the mountains no uniform groundwater horizon is recorded in large areas. Instead, water circulates in rock crevices. In the flysch Carpathians, water-bearing layers are in fracture zones or larger sand areas, whereas the hydrophilic layers such as shale, clay and loam have very poor water-bearing abilities. Better conditions for the collection of groundwater occur in these varieties of flysch in which sandstone complexes outweigh slates. This happens for example in Magura layers. Very high humidity occurs commonly in the rock-waste layer as a result of high rainfall, ground water resources and weak water-bearing abilities with simultaneous high retention capacity of the clay layers. Although soil is drained by numerous, deeply indented streams and some roads, in fact it rarely shows a shortage of moisture. The outflow of water from springs in the flysch Carpathians is generally low and variable. Natural groundwater outflows here have the form of springs, bog-springs, leaks and seepages. Springs appear wherever the boundary between water-bearing and hydrophilic layers intersects

the ground surface. Powerful spring water flow occurs in the Beskid Śląski due to high water-bearing capacity of the thick-bedded sandstones, which are present in these areas. Most often, however, water escapes to the surface in the form of bog-springs. The bog-springs occur in the form of oval ponds in flat places on the ridges or slopes. On steeper slopes, there are leaks, which because of their weak capacity and numerous occurrence play a significant role in moistening soil cover. Even lower capacity characterizes places of seepage. They often occur on cliffs and landslides. All three forms of water outflow (apart from springs) usually disappear in dry seasons (Małek and Gawęda 2006a, b; Małek and Krakowian 2009a, b; Astel et al. 2009; Małek et al. 2010c).

### METHODOLOGY

The present research was conducted in the largest mountain group in the Silesian Beskid, i.e. the Skrzyczne massif. Among the streams which drain the massif, two were selected whose catchments represent the southern (the Malinowski Stream) and northern (the Roztoka Czyrna stream) slopes of this massif.

### Field work

The research carried out in August 2012 consisted of juxtaposition of the available hydrological maps with the actual field conditions, identification of springs and streams and the course of their beds in order to update the data, assessment of selected parameters of these streams: indentation and width of the bed, the slope, the flow volume in characteristic diagnostic points located in particular climate and plant zones (the upper, middle and lower forest zones). Around springs and streams, the stand was described in terms of: species composition, density and the occurrence and composition of the regeneration layer. Attention was paid to the parts of the stand or else individual trees of admixture species which could yield seeds. Taking into account field conditions, there were made preliminary annotations concerning forest management recommendations on: stand and regeneration layer management, the species composition of cultures and underplanting as well as the species admixture form and methods of their introduction.

The field work included verification of the existence and course of streams and their nature (permanent or periodic) on tree stand maps. All cartographic documentation was submitted to the Regional Directorate of the State Forests in Katowice in order to update the numerical forest maps in the existing State Forests IT System (SILP) databases.

The features marked on the maps included: the actual course of streams and their nature (permanent or periodic) with a division into the existing ones and the ones added against the background of the division of the forest surface, contour lines, major roads, climate and plant floors as well as forest habitat types.

We also ascertained total length of streams, catchment areas and the areas along stream beds by adopting variable distances from the beds, depending on climate and plant zones and the slope gradient: 5 m in the upper forest zone, 10 m in the middle forest zone, 20 m in the lower forest zone on both sides of the bed and in the headwater area within the radius of 10 m from a spring.

#### **Cartographic work and SILP data development**

The extent of the catchment was determined using the Spatial Analyst extension for ArcGIS software. In order to reduce time-consuming calculations, the spatial range of the stream was determined with a margin allowing for proper generation of the digital terrain model (DTM), based on the available contour lines.

The digital terrain model (DTM) based on the contour lines was generated after excision of the contour lines using the range of the stream and by changing the contour changes to points of known height, and then by interpolation using the tool: Spatial Analyst > Interpolation > Topo to raster with raster cell size of  $4 \times 4$  m.

The next step was to define the stream catchment using a number of tools from the tool box Hydrology, extension Spatial analyst. This was done in accordance with the software manufacturer's recommendation in the following order:

- Flow directions – Spatial Analyst > Hydrology > Flow Direction
- Accumulation Spatial Analyst > Hydrology > Accumulation
- Flow points Spatial Analyst > Hydrology > Snap Pour Points (based on stream linear layer identifier ObjectID)

- Catchments Spatial Analyst > Hydrology > Watershed (flow directions and flow points)

As a result of the analyses, the ranges of the stream catchments were determined and further analysis was limited to these.

#### **Determination of the impact of streams on habitat humidity depending on the climate and plant zone and the slope**

In order to reflect the impact of the slope, on the basis of the DTM slopes were calculated (Spatial Analyst > Surface > Slope) in degrees. Then the raster of the slopes was calculated so that in the resulting raster the cell values corresponded to the adopted percentage of reduction of the width of the stream impact on habitat humidity (Spatial Analyst > Reclass > Reclassify).

Due to the fact that all further analyses were carried out in the vector model, the raster of the slope was converted to the vector layer. In the next step, in order to include the factor of climate and plant zone in the analysis of stream impact on habitat humidity, the layer of slopes converted to percentage was intersected with that vector layer (the layer used was the one prepared in earlier studies on the basis of the ASTER-GDEM model). The ASTER\_GDEM model was used to prepare the layer of climate plant zones. ASTER\_GDEM DEM accuracy (with the standard deviation of 7–14 m) is sufficient to calculate climate plant zones. Next, the buffer attribute was added to the resulting layer, which records in meters the adopted area of stream impact on habitat humidity, depending on the mountain forest zone. It was found that for lower, middle and upper forest zones, the area of stream impact was 20, 10 and 5 metres, respectively. The layer (buffer width) obtained as a result of the intersection of these layers (i.e. forest zones) contained the intersections of the slopes and mountain forest zones, allowing further calculations taking into account the influence of the factors of slope and mountain forest zone.

After intersecting the linear stream layer with the polygon layer of buffer width (Analysis Tools > Proximity > Buffer) it was possible to generate polygons of the stream impact on habitat humidity. Buffer width was calculated using the following formula:

$$\frac{1}{2} \text{ of stream width} + \frac{1}{2} \text{ of buffer (in respect of forest zone)} \times \text{percentage based on slope} / 100$$

According to the adopted assumption: for the slopes from 1 to 20 degrees, the buffer of the stream impact was not reduced; for the slopes between 20 and 40 degrees the impact was reduced to 80%; for the slopes from 40 to 60 degrees the assumed reduction was to 60%; above 60 degrees the assumed width of the buffer of the stream impact on habitat humidity was reduced to 20% for each climate and plant zone.

The stream layer was prepared so as to determine whether a stream is documented on numerical forest maps (LMN) of a forest district as indicated by the field SLMN with values: 1 – is documented on LMN, 0 – is added after stock-taking in field. Another important attribute of the stream layer allowed identification whether a given stream was permanent or periodic. This was indicated by the field called: permanent with values: 1 – permanent stream, 0 – periodic stream. The generated polygonal layer of stream buffers inherited the above-mentioned attributes of the stream layer, which allowed a detailed analysis of the results.

Next, the layer of stream impact buffers was combined (Analysis Tools > Overlay > Union) with habitat layers on the basis of the study of soil and habitat elaborated for the Roztoka Czysta stream and the habitats according to descriptions done for both streams in the LAS database of the State Forests IT System (SILP).

To allow the analysis of the results in respect of mountain forest zones, the resulting layers were intersected with the layer of mountain forest zones so that the attribute of mountain forest zone was added to the resulting layers.

## RESEARCH RESULTS AND DISCUSSION

The total length of watercourses draining the northern slope of the Skrzyczne massif and belonging to the Roztoka Czysta stream catchment is about 8.7 kilometers (one stream was not located; re-verification will be performed in the high water period in 2014). The total length of watercourses draining the southern slopes of this massif (the Malinowski stream catchment) is 17.3 km. One of the watercourses flows, beyond the forest, into the Żylica river and then to Żywieckie Lake. Another watercourse flows into the Leśnica river (the Leśnianka river), which flows into the Soła river, then to Żywieckie Lake. Therefore, they supply water to

a drinking water reservoir which is important to the region.

In the Roztoka Czysta stream catchment, 15 springs are located, including 7 springs of periodic streams and their beds in the initial course. In the Malinowski stream catchment there were, respectively, 23 and 13 springs (fig. 1 and 2).

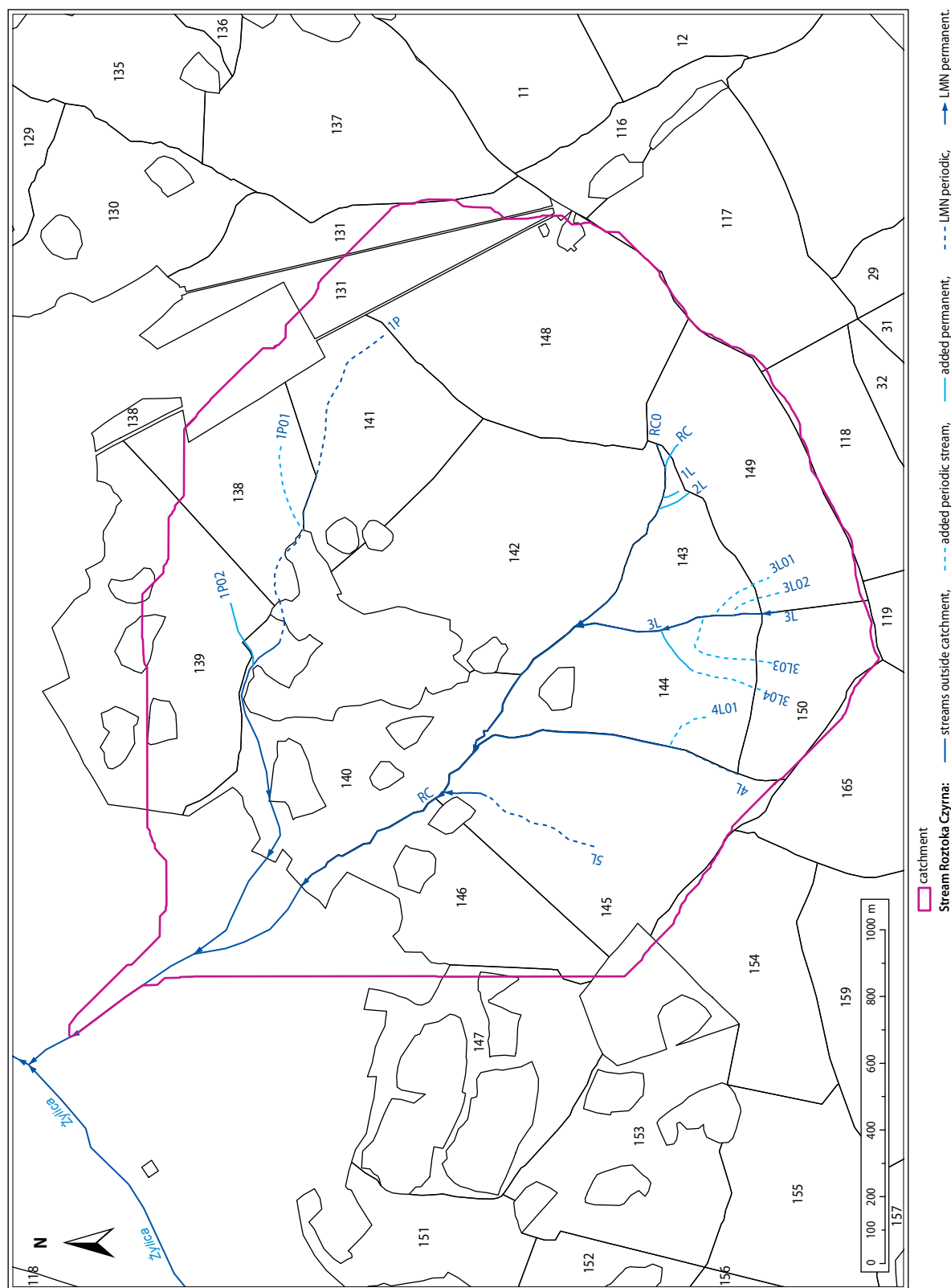
In the former catchment, the total length of periodic watercourses was about 40% and of permanent ones about 60% whereas in the latter catchment, they were, respectively, about 18 and 82% (tab. 1, fig. 1 and 2), which reveals a less favorable water balance of the northern slope, due to the arrangement of the geological layers and the composition of the bedrock there.

**Tab. 1.** The total length of watercourses in the catchments of: the Roztoka Czysta stream (RC) and the Malinowski stream (M) in climate and plant zones in the Skrzyczne Massif

Climate and plant zone	SLMN	Type	RC (m)	M (m)
Upper forest zone	added	periodic	1086	371
		permanent	303	474
	SLMN	periodic	498	0
		permanent	333	940
Middle forest zone	added	periodic	269	1709
		permanent	76	51
	SLMN	periodic	1199	323
		permanent	1014	4942
Lower forest zone	added	permanent	201	132
	SLMN	periodic	399	647
		permanent	3360	7701

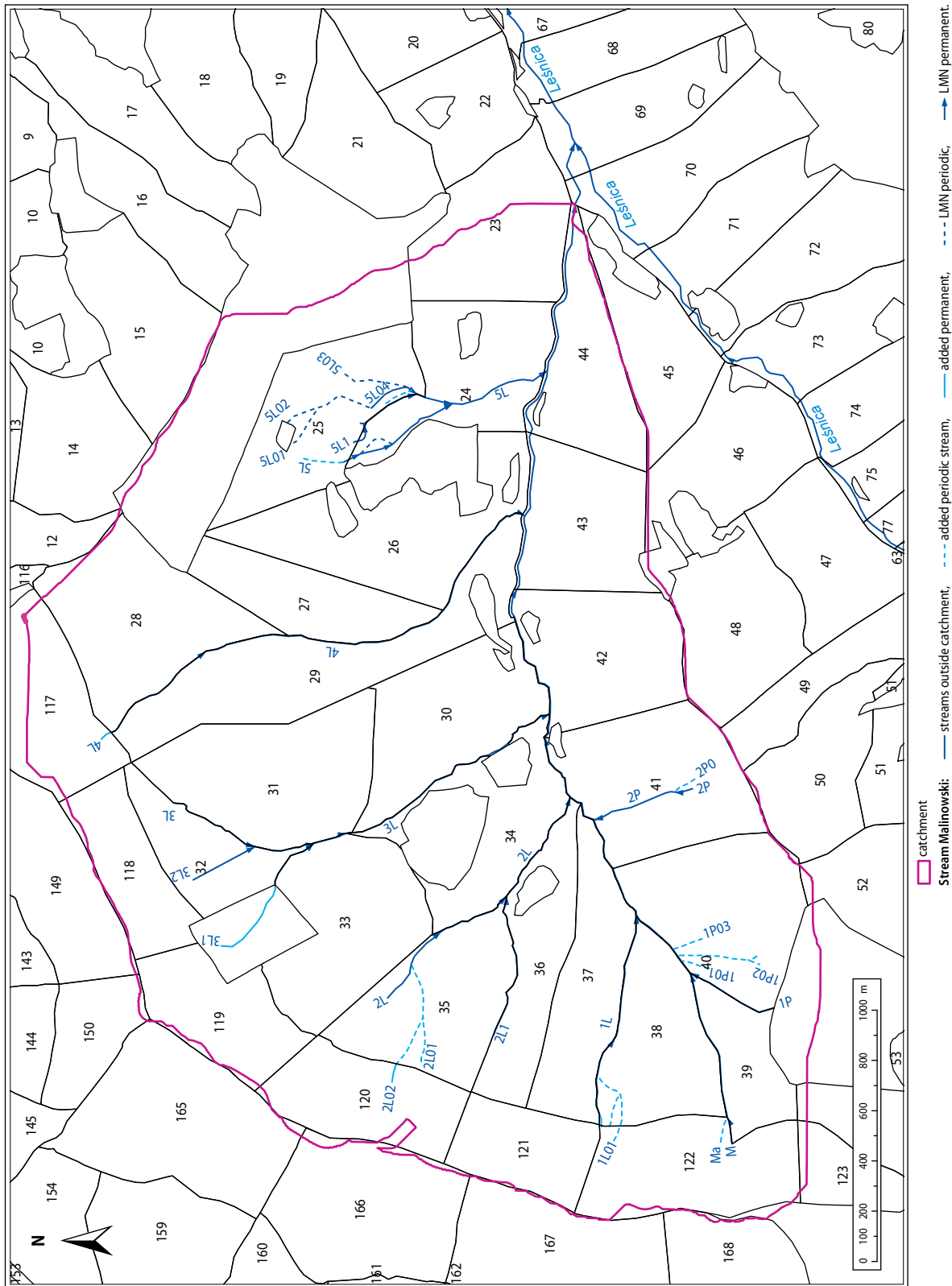
Explanation: SLMN – the existing watercourse on the numerical forest map.

As much as 22% of the total length of the examined watercourses on the northern slopes of the Skrzyczne massif and about 16% on the southern slopes were not recorded on the numerical forest maps. This demonstrates the need to update the hydrological network during the future preparation of the forest management plan. Particular attention should be paid to the initial sections of watercourses (in the upper and middle forest zones), in which the “added” streams constitute respectively about 90 and 95% of the total



**Fig 1. Location of springs and watercourses in the Roztoka Czarna stream catchment (RC) on the northern slopes of the Skrzyczne massif in Bielsko District**





length of streams in this group (tab. 1, fig. 1 and 2). The inventory of courses should be made in the period of low water. It will then be possible to identify areas vulnerable to humidity fluctuations during the growing season. In the Roztoka Czysta stream catchment, most of such areas are in the upper and middle forest zone (with an equal share) while in the Malinowski stream catchment a larger deficit is also present at high altitudes, but mainly in the middle forest zone (fig. 1 and 2).

The Roztoka Czysta stream catchment area is 333 hectares, whereas the Malinowski stream catchment area is about 786 ha (tab. 2). Within the first catchment, approximately 42% of its area belongs to the upper forest zone, about 34% is situated in the middle forest zone and about 23% – in the lower forest zone. Within the Malinowski catchment, the shares of the area in climate and plant zones amount to approximately 28, 39 and 33%, respectively. Among the

forest site types in the Roztoka Czysta stream catchment, the dominant ones in the upper forest zone are: mountain coniferous forest (BG) and mixed mountain coniferous forest (BMG), in the middle forest zone: mixed mountain coniferous forest (BMG) and mixed mountain forest (LMG). In the lower forest zone, there are mixed mountain forest (LMG). In immediate vicinity of the springs, the situation is analogous but with less variation (fig. 3 and 4). The comparison of forest site types (tab. 2) showed that in both Forest Districts, in the analysed climate and plant zones, the area of humid forest sites distinguished in the forest management is negligible (below 0.5%). A similar result was also obtained for the catchments examined in the present study after analysing the forest management plans. In the Malinowski stream area humid forest sites do not exist at all while in the Roztoka Czysta stream area they occur only in the lower forest zone in an area of approximately 5.5 hectares. However, dur-

**Tab. 2.** The share (ha) of forest site types in climate and plant zones in the Forest Districts of Bielsko and Węgierska Górka (according to the current forest management plans) in areas adjacent to springs and watercourses in the catchments of the streams: Roztoka Czysta and Malinowski in the Skrzyczne massif

Forest site type	Bielsko	Bielsko near streams	Roztoka Czysta Stream catchment area	Area adjacent to watercourses	Węgierska Górka	Węgierska Górka near streams	Malinowski Stream catchment area	Area adjacent to watercourses
Upper forest zone								
BWG	24.35		16.465				2.64	
BG	85.47	0.04	59.614	0.02	142.13	1.44	0.74	
BMG	377.24	3.32	58.396	0.98	565.32	7.92	149.29	0.15
LMG	20.1	0.06	0.963	0.09	63.50	3.24	67.21	0.60
			5.554				0.17	0.16
Middle forest zone								
BMG	549.68	15.58	59.112	1.13	1201.10	59.72	40.86	0.51
LMG	883.60	32.10	54.193	1.47	1342.30	79.98	257.73	6.97
LMGW	2.72							
LG					43.57	2.20	0.31	
			0.914	0.09			0.01	0.01
Lower forest zone								
BMG	356.17	9.44	1.110		772.90	42.96	0.16	
LMG	3729.54	213.06	65.633	4.91	3814.70	312.08	243.66	18.09
LG	360.19	31.12			935.74	103.08		
LGW	24.63	4.20	5.451	0.51				
LLG	1.36				10.17	4.36	0.04	0.02
			5.38	4.20			7.95	5.67



ing the inspection of the stands in field it turned out that in immediate vicinity of the watercourses humid habitats do exist, starting from the middle courses of the main streams and quite often at the mouths of streams flowing into the main streams, and even in higher locations. This is evidenced by the presence of hygrophilous trees. In this situation, according to the present authors, the designated areas along the watercourses (at a distance of 5 to 20 m from the river beds) are particularly valuable due to increased natural moisture and will constitute an important addition to this group of habitats, on condition of their determination and recording in the next forest management cycle. In the Roztoka Czyrna stream catchment, the total size of humid habitats is 13.5 hectares and in the Malinowski stream catchment – about 32.2 hectares. Separate, smaller divisions could only be created in lower mountain forest zones while at higher altitudes it would usually be sufficient to record the uniqueness of these habitats in the forest management plan, in the planning of forest crops (fig. 3 and 4).

Taking into account whole forest districts, for the examined climate and plant zones (upper, middle and lower), analogous areas calculated on the basis of hydrological maps and the digital terrain model are as follows: approx. 309 hectares (Bielsko Forest District), and approx. 613 hectares (Węgierska Górka Forest District). The management of these areas is possible in a few years, especially that not entire areas should undergo regeneration treatments.

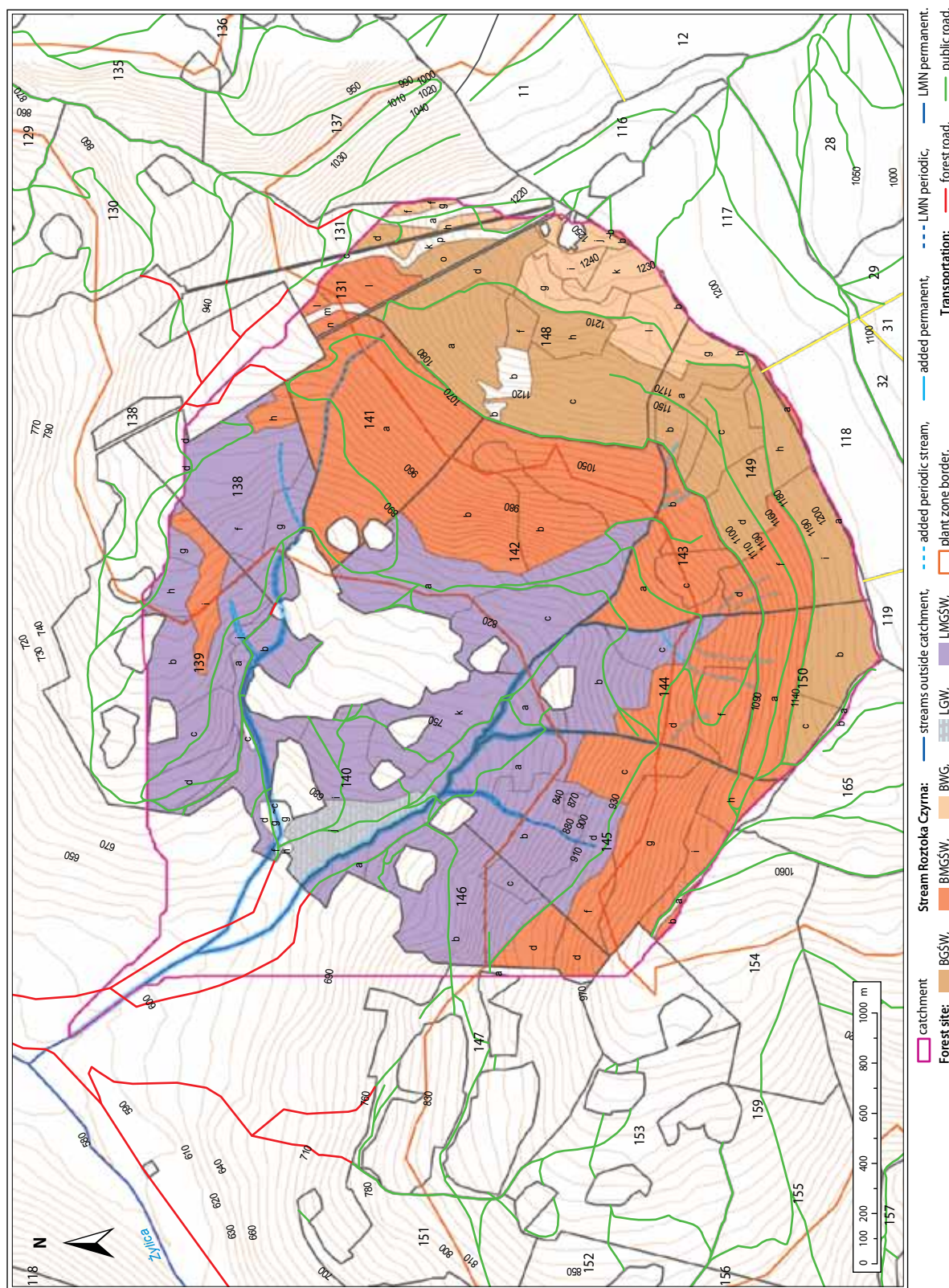
The analysis of the stand description in Barszcz et al. (2012) shows that essentially, in the upper forest zone, after disintegration of spruce stands there have remained scarce, weak specimens of beech and sycamore and occasionally fir, left during the clean-up of dead and dying spruce trees, mostly in vicinity of springs and stream valleys. In the open areas there are older cultures and young spruce stands with a small admixture of the above-mentioned and other species: mountain ash, silver birch and willow.

Single specimens of the 3 above-mentioned tree species (mountain ash, silver birch and willow), occurring among these spruce cultures and stands, have mechanically and abiotically damaged crowns, which is why there is no promise for abundant fructification. Therefore, it is necessary to introduce these species by planting. In the headwater areas within a radius of

10 m from the source and along the initial course of the streams (both permanent and temporary), within the distance of about 5 m from the stream bed, the sycamore should be introduced in groups in open areas, the fir should be introduced in biogroups and the beech – in small groups on micro hills under the cover of other parts of the stand or as individual trees and in gaps created in older and young cultures, using seedlings with the covered root system and mycorrhized. The common birch should be introduced in open areas with uncovered soil (sown with the use of shoots with fructification) and supplemented by groups of the mountain ash.

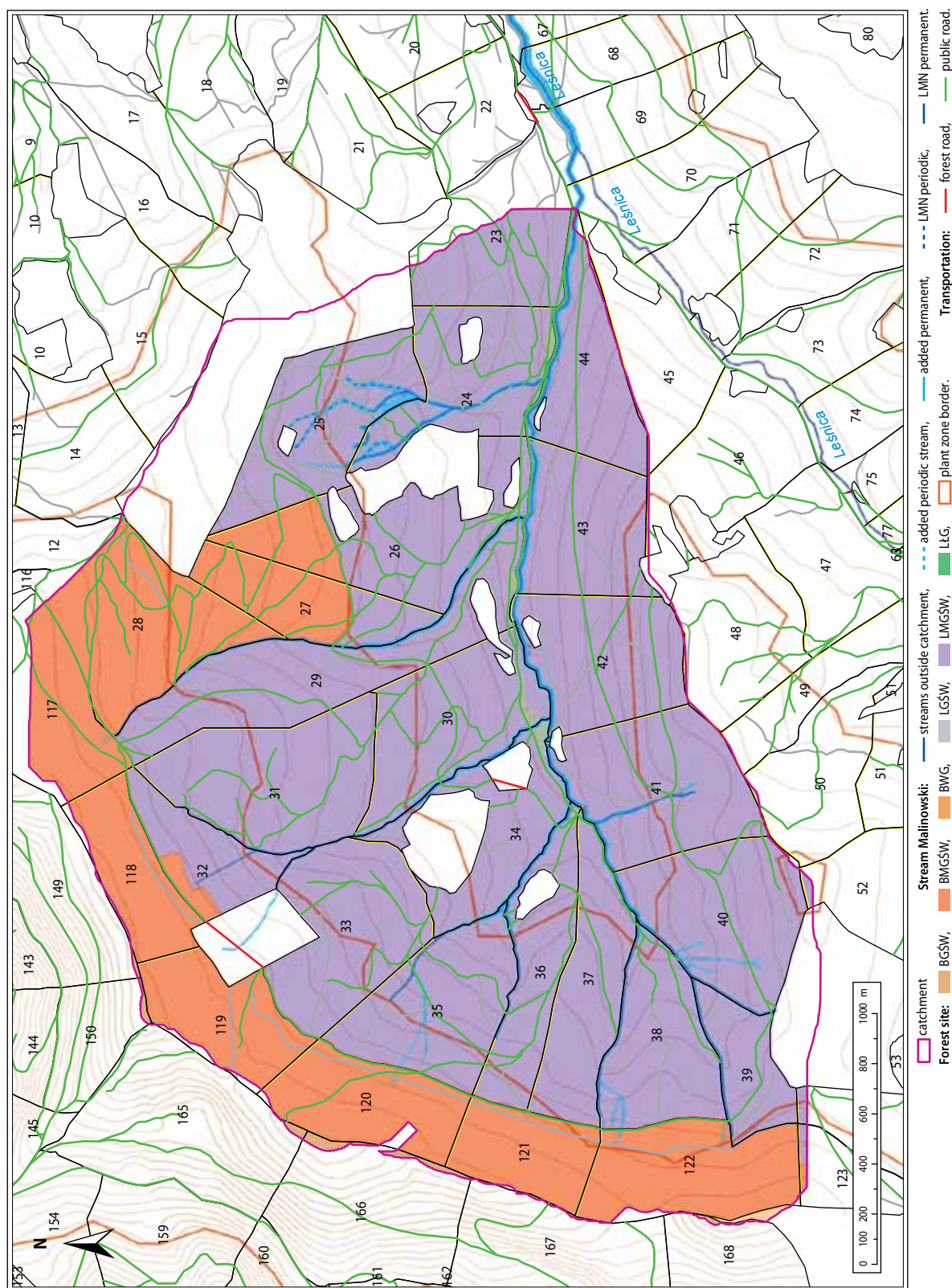
The analysis of stand description in Barszcz et al. (2012) indicates that in the middle forest zone in the immediate vicinity of watercourses, there occur the following fragments of beech stands of different ages: either solid beech stands or beech stands with an admixture of dying spruce together with the sycamore and fir in a good condition (from which seeds can be obtained). The areas remaining after stand disintegration, where there are older spruce greenwoods, should undergo rebuilding due to the risk that the spruce may die early, while beech greenwoods with a small admixture of sycamore and occasionally of fir, willow and common birch should be nurtured paying particular attention to the protection of fir. In the middle forest zone, in the case of both permanent and periodic streams, the same species as the above-mentioned ones (beech and fir) should be introduced in groups, up to 10 m from the streambed, using seedlings with covered root systems. Regeneration should be introduced in the existing gaps or those emerging in the future due to dying spruce trees. In existing forest stands, under-canopy cultures should be introduced in order to diversify the stand structure. Detailed management procedures will depend on the situation in a given fragment of the forest area. The desired form of the forest in the middle forest zone would be stands differentiated in terms of age and height, located in small areas and analogous to the selection forest structure in order to reduce the risk related to forest management by using many development stages and species.

In the lower mountain forest zone, the least affected by spruce disintegration (Barszcz et al. 2012), dense stands occur in large areas, especially beech stands with admixtures of other species or remains of spruce



**Fig. 3.** Zones for forest culture management in immediate vicinity of springs and watercourses in the Roztoka Czarna stream catchment (RC) on northern slopes of the Skrzyczne massif in Bielsko Forest District with reference to forest site types and climatic and plant zones





**Fig. 4.** Zones for forest culture management in immediate vicinity of springs and watercourses in the Malinowski stream catchment (M) on southern slopes of the Skrzyczne massif in Węgierska Górka Forest District with reference to forest site types and climatic and plant zones

forests of different ages. In stream valleys, especially near stream beds, there are admixtures of fir, sycamore and occasionally other species. At the mouths of streams and in the main stream valleys (in their further course) the species that appear in different shares are: ash, aspen, gray alder and bird cherry, and in lower altitudes – occasionally black alder (the Roztoka Czysta stream), small-leaved linden and common oak (the Malinowski stream). There are also numbers of mid-forest clearings (on the left bank of the Malinowski stream). A greater diversity of species characterises the catchment of the Malinowski stream, flowing only through wooded areas, at whose mouth to the Leśnica river there is a fragment of mountain riparian forest with ash, aspen, black alder, and, on the forest edge – with bird cherry. The lower section of the Roztoka Czysta stream is already outside of the forest area, in a built-up area.

Field observations (Barszcz et al. 2012) show that in the lower mountain forest zone, and especially in the major stream valleys, there occur dense and stable stands (with the exception of the areas remaining after dead spruce) with a rather diverse species composition. For this reason, in the areas within 20 m from the watercourses, and locally even farther, there should be introduced the same main species which are recommended for the middle mountain forest zone, i.e. the fir and beech under the canopy, whereas in the existing (but currently rare) or future gaps remaining after spruce death – the sycamore or other species with greater light requirements. Most of the existing stands require only improvement cuttings in order to control the species composition and improve stand vertical structure.

This forest zone also needs reconstruction of the existing, solid spruce stands – although they may now be viable – starting from the young forest stage, due to the danger of disintegration of these stands in the near future. Particular care should be extended to the appearing, valuable fir and sycamore regeneration. In this forest zone, it is also possible to introduce: the ash, mountain elm, bird cherry and gray alder, and in the lowest sections – the small-leaved linden and Norway maple. The existing mid-forest meadows should be mowed. In this forest zone, there is a sufficient seed base of the main species and some admixture species, and only the latter would have to be successively complemented (Barszcz et al. 2012).

## CONCLUSIONS

1. It is necessary to update the hydrological network in subsequent cycles of forest management. Particular attention should be paid to the initial sections of the streams in the upper and middle mountain forest zones because of their periodic disappearance and course change. Inventory on the watercourses should be carried out in the period of low water. It will then be possible to identify areas vulnerable to fluctuations in humidity during the growing season.
2. In the analysed climate and plant zones in both Forest Districts, the area of humid forest sites, distinguished by forest management plans, is negligibly small. Field observation of the stands showed that in immediate vicinity of watercourses humid habitats occur starting from the middle courses of the main streams and quite often also at the mouths of watercourses flowing into the main streams, and even at higher altitudes. This is evidenced by the presence of hygrophilous trees.
3. The areas distinguished along watercourses (at the distance of 5 to 20 m from their beds) are particularly valuable due to increased natural moisture and may be an important addition to the group of humid habitats, provided their determination and recording in the next cycle of forest management. Separate, smaller divisions could only be created in the lower mountain forest zone, while at higher altitudes it would usually be sufficient to record the autonomy of these habitats in forest management plans during forest culture planning. The management of these areas is possible in a few years, especially that not entire areas should undergo regeneration work.

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